China's distant water fisheries in the 21st century

Alternative titles: **Estimating the catch of China's distant-water fleets from 2000-2011;** or **China's distant-water fishery catches, 2000 to 2011**

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Running title: China's distant water fisheries catch

Abstract

We conservatively estimate the distant-water fleet catch of the People's Republic of China for 2000-2011, using a newly assembled database of reported occurrence of Chinese fishing vessels in various parts of the world, and information on the annual catch by vessel type. Given the unreliability of official statistics, uncertainty of results was estimated through a regionally stratified Monte Carlo approach which documents the presence and number of Chinese vessels in Exclusive Economic Zones, then multiplies these by the expected annual catch per vessel. We find that China, which over-reports its domestic catch, substantially under-reports the catch of its distant-water fleets. This catch, estimated at 4.6 million t·year^{-1} (95% central distribution: 3.4-6.1 million t·year^{-1}) for 2000 to 2011 (compared to an average of 368,000 t·year^{-1} reported by China to FAO), corresponds to an ex-vessel landed value of 8.93 billion €·year^{-1} (95% central distribution: 6.3-12.3 billion). Chinese distant water fleets extract the largest catch in African waters (3.1 million t·year^{-1}, 95% central distribution: 2.0-4.4 million t), followed by Asia (1.0 million t·year^{-1}, 0.56-1.5 million t), Oceania (198,000 t·year^{-1}, 144,000-262,000 t), Central & South America (182,000 t·year^{-1}, 94,000-299,000 t) and Antarctica (48,000 t·year^{-1}, 8,000-129,000 t). The uncertainty of these estimates is relatively high, but several sources of inaccuracy could not be fully resolved given the constraints inherent in the underlying data and method, which also prevented us from distinguishing between legal and illegal catch.

Keywords: Distant-water fishing; Illegal, Unreported and Unregulated (IUU) catch; Management, Control and Surveillance of fisheries; Monte Carlo method.

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Introduction

The world fisheries catch has been stagnating and probably declining since the late 1980s (FAO, 2011), despite a strong increase in fishing effort, notably in Asia (Anticamara et al., 2011, Watson et al., 2012). This decline, which appeared earlier in regions of the world where fisheries where first industrialized, e.g., in northwestern Europe, triggered a generalized expansion of industrial fisheries (Swartz et al., 2010). This was soon manifested in the development of dedicated distant-water fleets and fisheries, first by the United Kingdom and other European countries and the USA, later joined by the former Soviet Union, and by Japan and South Korea (Bonfil et al., 1998).

By the end of the 20th century, the People's Republic of China (here referred to as 'China', and excluding Taiwan, Hong Kong and Macau) had also become a major distant-water fishing nation (Mallory, 2012a, Mallory, 2012b, Xue, 2006). However, at first, China lacked the specialized vessels required for distant-water fishing, and the infrastructure required for supplying such vessels. Thus, initially, China simply 'exported' its coastal fleet, mainly consisting of bottom trawlers, to the waters of foreign countries it could operate in (Pang and Pauly, 2001).

At the onset of the 21st century, however, Chinese distant-water fisheries had changed, with specialized 'catcher' vessels (bottom trawlers, but also purse seiners, squid jiggers, longliners, etc.) linked to mother-ships delivering their catch to strategically located freezing and processing facilities, and supplying local, international and its own domestic markets (Mallory, 2012a, Mallory, 2012b). Also, China began to supply local infrastructure including wharves and port facilities. These are remarkable achievements in technology, logistics, and

business, mirroring other sectors of the Chinese economic expansion into the rest of Asia (Gaulier et al., 2007), Africa (Zafar, 2007, Beuret et al., 2008), Latin America (Ferchen, 2012) and Oceania (Wesley-Smith, 2007). In other words, Chinese distant-water fisheries have become globally important economic actors.

Chinese fisheries statistics

Unfortunately, what did not improve in the transition to the 21st century – occasionally seen as the start of an age of transparency (Sifry, 2011) – is the tendency toward secrecy in fisheries data, and the near complete disregard for public accountability of the use of public resources (Mallory, 2012a). Thus, there are no publicly accessible databases of access agreements between China (or Chinese companies) and the countries in whose Exclusive Economic Zones' (EEZs) Chinese fishing vessels operate. Such a public database exists, for example, in the European Union (EU), which provides in its law database (http://eur-lex.europa.eu, accessed July 2012) all texts related to fishing access agreements with other countries, which can be used for access analyses and examination (Kaczynski and Fluharty, 2002, Kalaidjian, 2010, Obaidullah and Osinga, 2010, Le Manach et al., 2012). Therefore, the activities and catches of the Chinese distant-water fleets are, in the public eye, almost completely undocumented and unreported, and thus may include all aspects implied by the 'IUU' (Illegal, Unreported & Unregulated) acronym (Bray, 2000, Mallory, 2012a). Thus, while Chinese distant-water fishing in a given EEZ may be perfectly legal (i.e., with complete access agreement negotiated between China and the host country), they may still be 'unreported'. Note, however, that there is, in recent years, a trend toward private companies from EU countries negotiating private agreements with host countries (or host country companies)

which are, as well, generally not publicly available either, and pose public accountability concerns (F. Le Manach, unpublished data).

The Chinese fisheries statistics pose a related problem. The reasons why China over-report the catch of its domestic marine fisheries (Watson and Pauly, 2001) were discussed in Pang and Pauly (2001), and essentially are the result of a planned centralized economy that rewards individuals for appearing to fulfil the plan (thus providing a powerful incentive for over-reporting production), combined with the absence of an independent statistical system after the privatization of previously exclusively state-owned fishing fleets. These factors continue to be at work in the Chinese marine fisheries sector, and are also the reasons why it may take considerable time until China submits to the Food and Agriculture Organization of the United Nations (FAO), of which it is an influential member, accurate catch statistics (Figure 1), despite some recent attempts at corrections (FAO, 2011). Recently, an initiative to develop a more effective statistical system for domestic fisheries has been developed, although such data are limited for domestic use only. In contrast to over-reported domestic catches, the secrecy alluded to above, together with the absence of an independent statistical system, combine to foster non-credible low annual catch reports by China to FAO – about 368,000 tonnes on average for all Chinese vessels operating outside FAO Statistical Area 61 (Western North Pacific), where China is geographically located (Figure 2).

Estimating China's distant water catches

Given these circumstances, obtaining a more accurate (even if likely imprecise) estimate of the actual catch of Chinese distant-water fleets must be based entirely on non-official sources. Consequently, we used methods which rely on the fact that any collective activity of the scale

considered here is bound to generate a ‘shadow’ on the societies it is embedded in, and on which it impacts (Pauly, 1998). From this ‘shadow’, the scale of the activity in question can be inferred, if often imperfectly and thus requiring further examination.

The second conceptual tool at our disposal is the concept of a (large) Fermi solution. In physics, when faced with the need to estimate unknown quantities from limited data, an approach is often used named after the physicist Enrico Fermi.

This is often illustrated by his estimation of the number of piano tuners in Chicago, in the absence of specific data. For this, he broke the problem down into parts about which he did have data - number of pianos per households, number of households in Chicago, frequency with which pianos needed to be tuned, etc., then computed his estimate (von Baeyer, 1993). Another example of this is the ‘Drake Equation’, used to estimate the number of extraterrestrial civilizations in our galaxy, based on the number of stars it contains, the number of potentially life-bearing planets per star, the fraction of such planets with some forms of life, etc. What is obtained with this method is not a definitive number, but rather a reasonable estimate, on the basis of which one can then identify critical steps requiring further examination.

Fermi solutions can be made vastly more useful by combining known parameters with the Monte Carlo method (Buckland, 1984), to quantify the level of uncertainty associated with the estimates. The Monte Carlo method considers the uncertainty associated with each parameter (or terms of the equations in question), and is extensively used in fisheries research, where high uncertainties are the norm (see e.g., Rosenberg and Beddington, 1987, Uhler, 2011), especially regarding catches (Ainsworth and Pitcher, 2005, Tesfamichael and Pitcher, 2007).

Herein, the solution is recomputed thousands of times, by randomly selecting different values for each parameter drawn from the probability distribution specified for each. This helps to quantify the range of values and the level of uncertainty of the estimates from the Fermi solution.

Thus, we shall here present the data which allow a reasonable preliminary estimate of the catch of Chinese distant-water fleets to be derived (see Online Supporting Materials for details of sources), explain our computational methods, assess their uncertainty, outline the results and finally discuss some of their implications. Additional goals of this study are to document an approach which could be used to estimate the foreign catch of other countries with large and problematic distant-water fleets, e.g., Spain (Knecht, 2007), and thus allow more accurate assessments of the status of global fisheries status, for which accurate catch statistics are essential (Kleisner et al., 2012).

Material and Methods

We define ‘Chinese vessels’ as boats with officers and crew from the People’s Republic of China (but excluding the Macau and Hong Kong Special Administrative Regions, which do not have distant-water fleets, and Taiwan, which does), irrespective of their flag. Hong Kong is, however, where the large Pacific Andes Corporation is headquartered (partly owned by the Chinese Government), and which operates in 32 countries (Pacific Andes, 2012). Pacific Andes’ vessels, for the most part included in this account (if under diverse flags), were involved in massive overfishing in the Southeast Pacific (Rosenblum, 2012). We made the above vessel definition choice for two reasons. Firstly, because there are likely few (if any) instances in which a fishing boat that is not owned, directly or indirectly, by a Chinese firm

(irrespective of the flag flown) is operated by Chinese officers and crew; and secondly, because of the widespread use of ‘flags of convenience’ as well as ‘charter’ and ‘joint venture’ arrangements, which render difficult the identification of actual beneficial ownership and prevent proper compensation through access fees. Indeed, the flag a vessel is flying often has little bearing on the actual targeted disposition and associated profit ownership of the landed catch (Griggs and Lugten, 2007).

Outside of Africa, we found no instance of vessels with Chinese officers and non-Chinese crew. We found only one reported instance of a Taiwanese vessel, operating off the Pacific Coast of Costa Rica, being crewed and captained by mainland Chinese (see Online Supporting Materials). In West Africa, local crews are frequently taken on board of Chinese-flagged and Chinese-owned vessels (as they are on Korean, EU, and other vessels), to work for the most part as the lowest tier crew and fish processors. What is significant about this is that often these men are not paid in cash wages, but rather in frozen boxes of what are called ‘trash’ fish. These are species that are not considered to have any value on the Chinese or international markets, but can be sold locally. It is then up to the local crew to obtain whatever price they can for these fish in return for their labour. Not only does this compensation method mean that these crews are likely substantially underpaid, but also that this fish enters the local market unreported to local authorities (D. Copeland, unpublished data). However, the method outlined below implicitly accounts for such catches.

Catch estimation procedure

The procedure used here to estimate the catch by Chinese distant-water fleets consist essentially of 5 steps:

1) Establish the presence of Chinese vessels in the EEZ of a given country and year;

2) For countries and years where such presence was established, record the number of vessels involved, or assign a likely number of vessels to that country and year, given the nature and contents of the available document(s), including for neighboring countries;

3) Assign an annual catch in tonnes and catch value (in Euro, with 1 € = 1.295 US$ in April 2005) to each vessel, by vessel type;

4) Repeat (3) for all countries and years, and add up catches and catch values across countries and territories; and

5) Conduct a Monte Carlo simulation by repeating step (4) 10,000 times for input values (number of vessels by country, catch per vessel, etc.) drawn from distributions whose shapes are determined by the values obtained in steps (1-3) or independently. Probability distributions of the estimated total catches and catch values of the Chinese distant water fleets are then calculated, from which we compute the means and associated uncertainty of the final results.

Details on these five steps are as follows:

(Step 1) Establish the presence of Chinese vessels in the EEZs of maritime countries

While, in most cases, ‘access agreements’ providing the legal basis of Chinese operations in the waters of a given country could not be located, there was ample documentation on the

presence of Chinese vessels, ranging from newspaper articles to websites, and from scholarly articles to academic research theses. This was ascertained via a comprehensive search of online and hardcopy literature by the authors and colleagues, using resources in Arabic, Chinese, Danish, Dutch, English, French, Italian, Japanese, Korean, Norwegian, Portuguese, Russian, Spanish and Swedish. This yielded, for the period considered here (2000-2011), over 500 sources with positive records (see Online Supporting Materials), covering 93 countries and their overseas territories, as well as the High Sea in the Atlantic, Indian and Pacific Oceans (Figure 2). Although it is widely recognized that absence of evidence is not evidence of absence, we are fairly confident that if we missed countries whose EEZ hosted Chinese vessels between 2000 and 2011, these operations were likely limited in scope, as they left no 'shadow' in the mass media or academic literature of the countries in question, nor on the website of Chinese firms or government entities. In cases where our team's expert opinion suggested that Chinese vessel were likely present, despite the lack of compelling evidence (e.g., in Nigeria or around the mainland of India), we estimated a very conservative number of vessels in step 2, which resulted in a very low estimate of catch in step 3 (see below).

(Step 2) Establishing the number of vessels involved

In numerous cases, the documents used to establish the presence of Chinese vessels in countries' EEZs or adjacent High Seas areas also indicated the number of boats (or their catch and/or catch composition). Thus, using the documents that attested to the presence of Chinese vessels in a given country, and the less abundant documents which estimated their numbers and other information on the world's maritime countries (notably their nationally reported catches, see www.fao.org and www.seaaroundus.org), we conducted 'country scoring' sessions. We ran 5 such scoring sessions of several hours each, where at least 10 *Sea Around*

Us project members (mostly co-authors of this contribution), most of whom have lived in and/or worked on the countries or regions in question, reviewed the available evidence for a country, and then independently 'scored' that country in terms of the number (and type) of vessels expected to be operating in that country's or territory's EEZ. The independent estimates thus generated were averaged, and their standard deviation was computed, as required for the Monte Carlo simulations. The entire procedure was run twice, once for the period 2000 to 2005 and once for 2006-2011 (see Online Supporting Materials).

(Step 3) Estimating annual catch per vessel type

The annual catch per vessel type was derived, along with its confidence interval, from the data assembled by Lam et al. (2011) for their study of fishing costs of global fishing fleets. Specifically, the data available for 5 types of gear/boat combinations were assembled and analysed, yielding a distribution of mean annual catch for each gear/vessel type (Table 1; Figure 3). The 5 vessel types used here were: (a) miscellaneous gear vessels (including gillnetters, non-tuna longliners, squid jiggers, etc.); (b) bottom trawlers; (c) non-tuna purse seiners; (d) tuna purse seiners; and (e) tuna longliners. Also, the mean ex-vessel price (**€**/t) and its likely range was estimated from a global ex-vessel price database (Sumaila et al., 2007) and the average catch composition of the above 5 gear/vessel type combinations (Table 1).

The distributions of the mean annual catch rates (Figure 3) and ex-vessel price ranges (Table 1) for each vessel type were rather wide; this was mainly because the catch and catch values of these vessels were not standardized for the size and other characteristics of the vessels. This should have a magnifying effect on the uncertainty around the final, aggregate estimates of catch and catch value.

(Step 4) Estimating the global catch of the Chinese distant-water fleet

The annual catch of Chinese distant-water fleets, by period and region (except for Japan, and North & South Korea in northeast Asia, see below), was estimated by multiplying the number of vessels of a given type (as obtained in Step 2) assigned to the countries of that region by the annual catch for that vessel type (as obtained in Step 3), and adding up the products to regional sums. A similar procedure was applied to the value of the catch through multiplication of the catch tonnage taken by each gear/boat combination by the corresponding ex-vessel prices in Table (1). Note that we do not deal here with discarded catches, although they can be assumed to be considerable (Zeller and Pauly, 2005).

(Step 5) Using Monte Carlo procedures to estimate uncertainty

Following standard Monte Carlo procedures, step (4) was repeated 10,000 times, each with a different set of inputs drawn randomly from the distributions associated with the different parameters. For the catch by vessel type, we assumed that the possible values follow a triangular distribution that is defined by a mid-point and the upper and lower limits (Figure 3). The distribution of these 10,000 estimates was then used to present an indicator of uncertainty, here the central 95% of distribution of Monte Carlo values (i.e., 2.5^{th} and 97.5^{th} percentiles) , of the midpoint estimates of catch and catch values.

Chinese catches in the waters of close neighbours

Due to their proximity to China, and hence their accessibility by the domestic Chinese fleet, Japan, North Korea and South Korea are known to host (legally and/or illegally) large numbers of Chinese coastal vessels in their EEZs. Thus, we applied alternative approaches for

estimating the Chinese catches in the EEZs of these three countries, while avoiding double-counting:

1) For the Chinese fleet operating in the Japanese EEZ, we used the mean of the quota specified annually by the bilateral Fishery Joint Commission under the China-Japan Fisheries Agreement of 1997 (see Online Supporting Materials) and treated these as realized catch. We assumed that catch in the years preceding these quotas was the same in as in the first year with a quota;

2) For South Korea, we similarly assumed that the quotas issued to Chinese vessels by the Korean Fisheries Information Service (Anon., 2012) were equal to the realized catch. We also assumed that their catch in the years preceding the issuance of these quotas was the same as in the first year with a quota; and

3) For North Korea, which has only a very small EEZ on the side of its coast that faces China, and whose EEZ in the Sea of Japan is not accessible to short and medium range Chinese vessels, we assumed that the catch by Chinese vessels is negligible.

Combined, the assumptions we made regarding the Chinese catches in the EEZs of Japan and at least South Korea generated estimates which may be realistic (see Table S1, Online Supporting Materials), as they are based on reciprocal quotas, where quota-busting behavior by one side would result in quota-busting by the other side. We also assumed that Chinese vessels are not fishing in Taiwanese waters (see also Kuo and Booth, 2011).

China fishing in the High Seas and Antarctica

The High Seas and Antarctica were also dealt with differently than other areas. We treated Antarctica, i.e., the area of responsibility of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR; www.ccamlr.org/ and www.seaaroundus.org/RFMO/1.aspx, see also Figure 2) as if it were a 'country', with its own estimate of vessel numbers of various types, and catch and catch values. For the other High Sea areas, we assumed that the vessels reported as fishing in the 'high seas' of the Atlantic, Indian and Pacific Oceans were the same ones that were reported to fish in the EEZs of adjacent coastal states, or their territories. This avoids potential double-counting, and will also tend to make our results more conservative.

Results

Overall, over 500 reports were obtained from the scientific literature, newspapers, magazines, other media outlets and websites, both Chinese and non-Chinese. These reports attested to the presence of Chinese vessels in the Exclusive Economic Zones of 93 maritime countries and/or their overseas territories, and in Antarctica (Figure 2; see also Online Supporting Materials). The only large regions of the world where Chinese distant water vessels do not appear to operate are the Arctic, the coast of North America, the Caribbean, and European waters (Figure 2).

Table (2) presents the estimated mean number of Chinese fishing vessels of various kinds estimated to operate in the EEZ (and/or adjacent high seas areas) of the countries and territories in 7 regions of the world ocean, in the period from 2000-2011 (see also Figure 4A).

Table (3) presents our main results, i.e., estimates of the catch by Chinese vessels in different regions of the world, with a measure of their uncertainty (95% central distribution, see also Figure 4B). Note that we do not present results by country as these are too uncertain; only in the aggregate is our method likely to generate reasonable results. We also abstain from presenting separately the results by period (2000-2005 versus 2006-2011), as there were, at the regional level, no significant differences between these two periods. There were significant differences in the number of vessels of various types for these two periods, and hence estimated catches for some countries, but as stated above, we consider our method to be less reliable when results are disaggregated to the level of countries.

As might be seen in Table (3), overall, Chinese fleets catch an estimated 4.6 million $t \cdot year^{-1}$ outside their domestic waters. In terms of regions, Africa is where Chinese distant-water fleets extract the largest catch, about 3.1 million $t \cdot year^{-1}$, followed by Asia (948,000 $t \cdot year^{-1}$ excluding Japan and South Korea, or slightly over 1 million $t \cdot year^{-1}$ with Japan and South Korea), Oceania (198,000 $t \cdot year^{-1}$), Central & South America (182,000 $t \cdot year^{-1}$), and Antarctica (48,000 $t \cdot year^{-1}$). The uncertainty surrounding these catch estimates is relatively high (Table 3), which is an expected feature of our results, given the underlying data used. We do hope that the readers will not choose one of the extremes of the 95% central distribution of our results to support preconceived notions about Chinese distant-water catches.

These catch estimates can be compared with the catches that China reports for its distant-water fisheries, which can be done using two different approaches. The first is relating our estimates to the Chinese reported catches that are assigned (by China and/or the FAO) to all FAO Statistical Areas other than Area 61 (i.e., the Northwest Pacific, which also includes Japan, North Korea and South Korea and the Russian Far East). On average, this was 368,000 $t \cdot year^{-1}$

(see Figure 1), or 8% of the global Chinese distant-water catch estimated here (Table 3) after subtraction of their average catch in Japan, (North &) South Korea and the Russian Far East (an estimated 42,217 t·year^{-1}). This estimate of 8% reporting is biased downward, however, because, as mentioned above, the Chinese distant-water fleets report some of their landings as 'national catch' of the countries in whose EEZ they operate (e.g., as joint ventures or charters), or as catch of the countries providing them with flags of convenience. Furthermore, FAO statistical data seem to contradict information provided by FAO country profiles, as the FAO country profile for China (http://www.fao.org/fishery/countrysector/FI-CP_CN/en) states that in 2004, China used 1,996 distant-water fishing vessels to catch 2.42 million t from fishing in the High Seas and the EEZ waters of 35 countries.

The other approach is to rely on the official Chinese government data (see Table S2 in the Online Supporting Materials), which suggest that the distant-water catches of China from 2000 to 2010 were about 1.1 million t·year^{-1}, i.e., less than one quarter of our estimate (Table 3). During a European Commission Conference (*RFMOs 'Fit for the Future'*) held in Brussels on June 1, 2012, Mr. Xiaobing Liu, the Director of the Division of International Cooperation, Bureau of Fisheries, Ministry of Agriculture, China, indicated that China's distant-water fleet consists of 1,600 vessels fishing in 37 countries and the High Seas, and catches 1.15 million t (http://webcast.ec.europa.eu/eutv/portal/archive.html?viewConference=15690). Note that the number of vessels in Table (2) is roughly compatible with the catch estimates in Table (3) if the vessels operating in nearby Korean and Japanese waters are discounted.

Our knowledge of the disposition of this catch is poor. For the West African region, field observations by one of us (D. Copeland), an interview we conducted with a knowledgeable Chinese national who was employed by a Chinese fishing firm operating in that region, and

scattered accounts documented in the Online Supporting Materials suggest that approximately one-third is landed locally, one third (mainly invertebrates and high value fish) goes to the international markets (notably the EU and Japan), with the remaining third (mostly medium and large demersal fish, and shark fins) going back to China.

Some countries have local landing requirements, e.g., Sierra Leone requires the landing of a percentage of 'bycatch', though this seems poorly defined and not really monitored (D. Copeland, pers. obs.). However, in West Africa at least, Chinese trawling interests often have influence because local markets have to a degree become dependent on their landings.

In contrast, Mallory (2012b) suggested that "Chinese companies sell about half of their catch, mostly the high-value species, to developed countries: the European Union, Japan and The United States", while Mallory (2012a) stated that approximately 54% of distant-water catches are transported back to China. Applying the latter percentage to our estimate of China's distant-water catch would lead to around 2.2 million $t \cdot year^{-1}$ being landed domestically while 1.9 million $t \cdot year^{-1}$ would be landed in or sold to foreign markets.

Discussion

The large number of project members involved in the estimation of the number of Chinese distant-water vessels operating in the EEZ of various countries (always >10 persons; including many of the authors of 'catch reconstructions' (sensu Zeller et al., 2007a) in the region of interest), and the independence of their individual estimates prior to computing the averages was to allow for the 'wisdom of crowd' effect to work. This enables a large number of informed estimates to converge towards the correct values, as they will do when they are truly

independent (see Surowiecki, 2005 for a detailed account, Galton, 1907 for the first well documented case, and Herzog and Hertwig, 2009 for recent methodological improvements). This approach is closely related to the 'Delphi method' (Linstone and Turoff, 1975), which, from rather shady beginnings (Dalkey and Helmer, 1951), graduated to a method ideally suited for fisheries research (Zuboy, 1981). It has been frequently applied to the estimation of fisheries catches (see e.g., Miller and Davidson, 1984, Pauly, 1986), or various biological parameters of fish (see e.g., Barrett, 2009).

On the one hand, our estimates of vessel numbers, although derived from the 'bottom up' (i.e., for individual countries and territories, then added up), are compatible with the few available 'top down' estimates of the size of the Chinese distant-water fleet. Thus, Mallory (2012b) estimated that "nearly 400 Chinese vessels" operated in West Africa, compared to our estimated 345 (Table 2), while Chen et al. (2008) indicated that 100 Chinese squid jigging vessels are operating in South America, compared to our estimated 98 (Table 2), pertaining to South America and some of parts of Central America.

Our overall estimated number of vessels (3,432) is larger than the mean number of officially reported Chinese distant-water fishing vessels (1,815; Table S2 in the Online Supporting Materials). However, our estimate includes over 2,500 vessels operating in the East China Sea within the EEZs of Japan and South Korea. These vessels operate exclusively within the continental shelf of the Northwest Pacific and are likely to be identified as coastal/offshore vessels in the Chinese Statistical Yearbooks, i.e., to be listed among the about 300,000 motorized fishing vessels operating along the Chinese coast (Blomeyer et al., 2012, FAO, 2011). Excluding the Chinese vessels operating in the waters of Japan and Korea from our total (Table 2) leaves us with 900 vessels as 'bottom-up' estimate of the size of the Chinese

distant-water fleet (i.e., about half the officially reported number of Chinese distant-water fishing vessels; Table S2 in the Online Supporting Materials). It is thus likely that our results underestimate the actual size of this fleet, and correspondingly underestimate the catches derived from vessel numbers, and the value of these catches.

Thus, we have here dealt with the issue of accuracy by using an approach yielding results that are very conservative, i.e., strongly biased downward. In term of their precision, our results have relatively narrow distributions (Figure 4), essentially because they are based on the addition of large numbers of independent products.

The midpoint estimate for ex-vessel value of all catches of the Chinese distant–water fisheries is 8.93 billion € (Table 4; Figure 4C), i.e., nearly 14% of the estimated total ex-vessel landed value of the world's reported catch of roughly 65 billion €, based on the ex-vessel price database documented in Sumaila et al. (2007). However, this 14% value is likely to be biased upward because our estimate of the Chinese distant-water landed value includes IUU catches, while the Sumaila et al. (2007) estimate of the ex-vessel value of global marine catch does not. Yet we now know, from the work of Zeller et al. (2006, 2007b, 2007a, 2008, 2011a, 2011b) and contributions in Zeller and Harper (2009) and Harper and Zeller (2011), that the catches reported by countries to the FAO, which formed the basis of the values in Sumaila et al. (2007), are systematically underestimated, by about 30-50% in developed countries, and often more than 100% in many developing countries.

In summary, we find that China, which has been shown to over-report (to FAO) its domestic marine catch (Watson and Pauly, 2001, FAO, 2011, Pauly and Froese, 2012), substantially under-reports (to FAO) the catch of its distant-water fleets. We estimate that China has a

distant water fleet of around 3,400 vessels, including its fleet fishing in neighbouring Japan and South Korea, or at least 900 vessels excluding its fleet in Japan and South Korea (Figure 4A). The annual catch of this fleet is estimated here at 4.6 million $t \cdot year^{-1}$ (95% central distribution: 3.4-6.1 million $t \cdot year^{-1}$) for the 12 year period from 2000 to 2011, including from the waters of Japan and South Korea. This is 4.5 million $t \cdot year^{-1}$ without Japan and South Korea (Figure 4B), corresponding to an ex-vessel value of 8.93 billion $€ \cdot year^{-1}$ (95% central distribution: 6.3-12.3 billion $€ \cdot year^{-1}$) including Japan and South Korea, or 8.76 billion $€ \cdot year^{-1}$ without Japan and South Korea (Figure 4B). The disposition of this catch is unclear, though there is evidence that some of it ends up on international markets, notably in the European Union (Mallory, 2012a, Mallory, 2012b).

In the spirit of fairness, we should re-iterate that our methodology does not allow for distinguishing legal from illegal catch, and that a least some accounts of ‘illegal fishing’ (see Online Supporting Materials) may refer to vessels that are fishing legally, but under access agreements which have not been made public, or using gears and/or targeting species not covered by these agreements (D. Copeland, pers. obs.). Chinese agreements are generally the most private and secretive, and are often only known to a few individuals within a host country’s Ministry (D. Copeland, pers. obs.). Thus, in analogy to our suggestion not to use the extremes of our percentile distributions to summarize our findings, we urge readers not to infer from the large fraction of apparently unreported (i.e., ‘IUU’) catches by the Chinese distant-water fleet estimated here that its catches consist only, or even mainly, of illegally caught fish. The acronym ‘IUU’ also includes ‘Unreported’ and ‘Unregulated’, and this study was an attempt to document what the total Chinese distant-water fleet catch could be, not to assess illegal activities.

The present study is based on a report and presentation (on July 11, 2012) to the Fisheries Committee of the European Parliament (Blomeyer et al., 2012), which concluded with the following recommendations, which are of general interest:

1. The FAO should insist on proper reporting of catches from China, both domestic and distant-water, by region and taxa. If required, China should provide funding to FAO so they can hire staff who would work with Chinese officials on cross-validating Chinese fisheries statistics;
2. Because item (1) may not be achievable quickly, the European Parliament should encourage the creation and fund, at a European university or think tank, a unit devoted to research on China's ocean affairs with emphasis on fisheries, staffed with personnel who read Chinese, and which would track sectorial developments, using standard econometric methods, and/or, when required, unconventional approaches, as was done here;
3. However, such studies would have to be conducted as part of broader international studies, because the practices of the Chinese distant-water fleets do not differ much from those of other countries in East Asia and Europe that also deploy distant-water fleets, the main difference with Chinese fleets being their size. Otherwise, the necessary dialogue with Chinese authorities and with Chinese scientists would be burdened by the suspicion that China is being singled out for practices which are, unfortunately, widespread in distant-water fisheries. In fact, concerted efforts in improving the norm of practice of international distant-water fleets are needed to provide incentive for all participants to take positive action;

4. The European Parliament should encourage all developing countries to realize that it is in their interest to make public all existing and future agreements with China and all other distant-water fishing countries, similar to current disclosure practices of EU fishing agreements. This may encourage a more virtuous competition, with terms more favourable to developing countries;
5. The European Parliament should encourage full disclosure about real beneficial ownership of distant-water fleets, as the present maze and complexity of re-flagged vessels, charters, joint ventures and flags of convenience tend to obscure and mask fishing operations to the extent that tracking of real trends and policy interventions become impossible; and
6. Even though we did not distinguish illegal fishing from legal access here, it would be necessary in the long run to ensure that illegal operations are being dealt with as criminal matters (see e.g., UNODC, 2011) and not as fisheries management issues. However, this again applies to all countries with distant-water fleets, and not only to China.

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Tables

Table 1. Fishing vessel statistics used for estimating the catch of Chinese distant-water fisheries. Extracted from the database documented by Lam et al. (2011); see also Figure (3). Prices are in 2005 real value.

Gear/boat type	Catch/vessel (t·year^{-1})			No. of vessels	Ex-vessel price (€/t)[5]		
	Mean	**Min.**	**Max.**	**N**	**Mean**	**Min.**	**Max.**
Miscellaneous gear boats[1]	221	5	1,211	52	1,493	439	3,617
Bottom trawlers[2]	1,256	16	26,135	269	1,501	466	3,965
Purse seiners (non-tuna)[3]	6,230	14	40,500	62	915	83	2,723
Tuna longliners[4]	284	57	1,277	21	2,195	724	5,183
Tuna purse seiners[4]	4,640	30	7,762	40	2,326	697	5,913

[1] Including gillnetters, non-tuna longliners, squid jiggers etc., targeting medium- and high-value fish (but not tuna), and squid (for squid jiggers);
[2] Targeting mainly demersal fish and bottom invertebrates, notably shrimp;
[3] Targeting mainly small to medium fish, such as sardine, herring, and mackerels;
[4] Targeting tuna, but with a large amount of by-catch, notably shark, in the case of longliners;
[5] Converted from real (2005) US$, using an IMF exchange rate for 2005 (http://www.imf.org; accessed 25 April 2012).

Table 2. Estimated number of Chinese distant-water fishing vessels operating in the Exclusive Economic Zones (and adjacent High Sea areas) of the maritime countries and territories of various regions, 2000- 2011.

	Number of vessels (by gear type)							
Region	**Misc. boats**	**Bottom trawlers**	**Purse seiners**	**Tuna longliners**	**Tuna purse seiners**	**Total**	**2.5th percentile**	**97.5th percentile**
West Africa[1]	31	256	35	22	1	345	290	398
East Africa[2]	5	13	1	22	7	48	36	63
Asia (excl. Japan & South Korea)[3]	67	76	8	45	17	213	175	254
Japan and South Korea	See Table S1, Online Supporting Materials for details on number of vessels by type					2,532	2,094	2,744
Oceania[4]	7	2	0	159	23	191	151	234
Central and South America	71	12	2	13	0	98	62	137
Antarctica[5]	2	0	3	0	0	5	2	8
Total	--	--	--	--	--	**3,432**	**2,910**	**3,734**

[1] Including: Algeria and Morocco all the way south to Namibia, but excluding Madeira (Portugal) and the Canary Islands (Spain);
[2] South Africa to Sudan including the islands of the Western Indian Ocean, except the Iles Eparses (‘Scattered Islands’; France) in the Mozambique Channel;
[3] Excluding Japan, North and South Korea, and Taiwan;
[4] Including Australia, Papua New Guinea, New Zealand, and the Small Island States of the Pacific;
[5] Area covered by Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR; www.ccamlr.org/ and www.seaaroundus.org/RFMO/1.aspx.).
[6] Standard deviation based on the same coefficient of variation as total number of vessels without Japan and Korea.

Table 3. Estimated annual catch by vessel type of the Chinese distant-water fleets from the Exclusive Economic Zones of maritime countries and territories (and adjacent high sea areas), 2000 to 2011.

	Annual catch by gear (1000 t)							
Region	**Misc. boats**	**Bottom trawlers**	**Purse seiners**	**Tuna longliners**	**Tuna purse seiners**	**Total**	**2.5th percentile**	**97.5th percentile**
West Africa	15	2,355.0	554.7	11.4	4.7	2,941	1,843	4,295
East Africa	2.7	119	18	11.7	29.5	181	86	317
Asia (excl. Japan and South Korea)	32.5	697	127	24.1	67.5	948	561	1,502
Japan and South Korea	See Table S1, Online Supporting Materials for details on catch by vessel type					106	74	151
Oceania	3.5	18.4	0	84.3	91.9	198	144	262
Central and South America	34	109.7	31.7	7	0	182	94	299
Antarctica	0.98	0	47	0	0	48	8	129
Total	--	--	--	--	--	**4,604**	**3,359**	**6,119**

Table 4. Estimated annual landed value by vessel types of the Chinese distant-water fleet from the Exclusive Economic Zones of maritime countries and territories (and adjacent high sea areas), 2000 to 2011.

	Landed (ex-vessel) value (billion €·year^{-1})							
Region	**Misc. boats**	**Bottom trawlers**	**Purse seiners**	**Tuna longliners**	**Tuna purse seiners**	**Total**	**2.5th percentile**	**97.5th percentile**
West Africa	0.03	4.74	0.7	0.03	0.01	5.52	3.23	8.75
East Africa	0.01	0.24	0.02	0.03	0.09	0.39	0.18	0.71
Asia (excl. Japan and South Korea)	0.06	1.4	0.16	0.07	0.2	1.89	1.10	3.17
Japan and South Korea	not estimated by vessel type[1]					0.17	0.12	0.24
Oceania	0.01	0.04	0	0.23	0.28	0.55	0.38	0.76
Central and South America	0.06	0.22	0.04	0.02	0	0.34	0.17	0.6
Antarctica	0.002	0	0.06	0	0	0.06	0.008	0.20
Total	**--**	**--**	**--**	**--**	**--**	**8.93**	**6.33**	**12.32**

[1] The 95% central distribution of the catch value for Japan and South Korea was estimated based on the overall variation of the catch value without Japan and South Korea.

Figures

Figure 1. Marine fisheries landings as reported by FAO on behalf of its member countries. **A**: Marine fisheries catches of China, as reported to FAO, featuring the small (13%) correction to the flat domestic catches decreed since 1998, which followed the questionable increase from the mid-1980s to 1998 (Watson and Pauly, 2001), and the non-credible low catch that FAO reports on behalf of China for its distant-water fisheries, i.e., outside of FAO area 61 (Northwest Pacific). **B**: Catches of the four major fishing countries and 'others' in the Northwest Pacific (FAO area 61), illustrating how radically the trajectory for the Chinese reported catch differs from that of the other countries in its region (modified from Pauly and Froese, 2012).

Figure 2. Exclusive Economic Zones (EEZ) of countries or territories where Chinese vessels were reported to operate in during 2000-2011, based on over 500 reports documented in the Online Supporting Materials. Note the very large size of China's claimed EEZ, which is the cause of disputes with Japan, South Korea, Taiwan and all Southeast Asian countries bordering the South China Sea, i.e., Brunei Darussalam, Indonesia, Malaysia, the Philippines and Vietnam (see, e.g., Smith, 1986, especially p. 28-29, on how EEZs ought to be designed and disputes resolved). Also note that Taiwan makes essentially similarly large claims as China, but does not attempt to enforce them.

Figure 3. Distribution of annual catch (in t·year^{-1}) by the five gear/vessel types common in Chinese distant-water fisheries. Note logarithmic scales on the x-axis, and the broad overlap of the five distributions, which tends to reduce the sensitivity of the overall results of this analysis from the country-specific assignments of vessel numbers to gear/vessel combinations. Based on vessel characteristics from multiple countries in the database assembled by Lam et al. (2011). The triangular distributions are those used for the Monte-Carlo simulations (see text).

Figure 4. Distribution of key estimates pertaining to the Chinese distant-water fleets, resulting from 10,000 Monte Carlo simulations. **A:** Number of Chinese fishing vessels of all types in the distant-water fleet, 2000-2011; **B:** Annual catch (t·year^{-1}); and **C:** Annual landed value (billion €·year^{-1}). Data relate to all countries excluding Japan and (North &) South Korea.

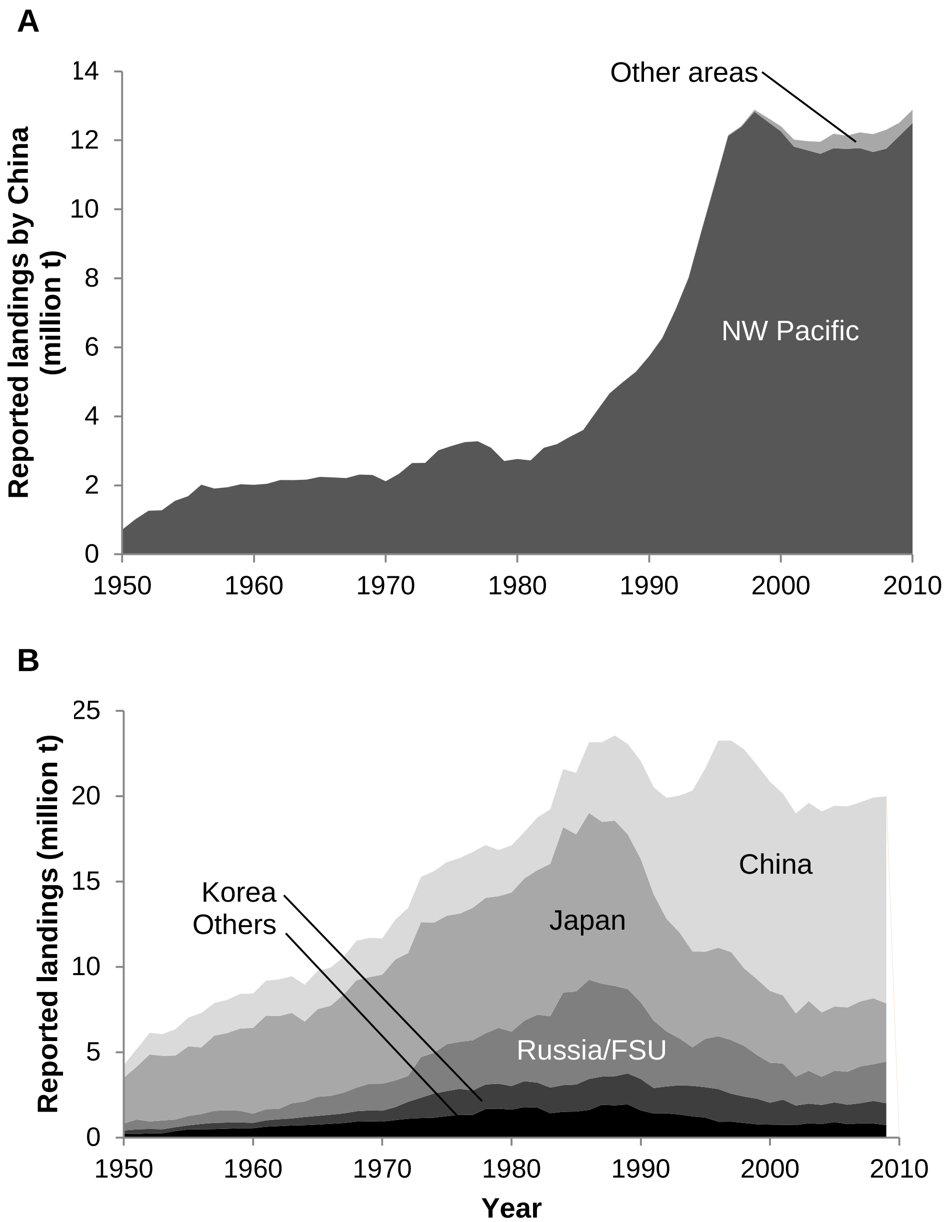
A
Reported landings by China (million t)
Other areas
NW Pacific
0
2
4
6
8
10
12
14
1950
1960
1970
1980
1990
2000
2010
B
Reported landings (million t)
Korea
Others
Japan
China
Russia/FSU
0
5
10
15
20
25
1950
1960
1970
1980
1990
2000
2010
Year

Fig. 1

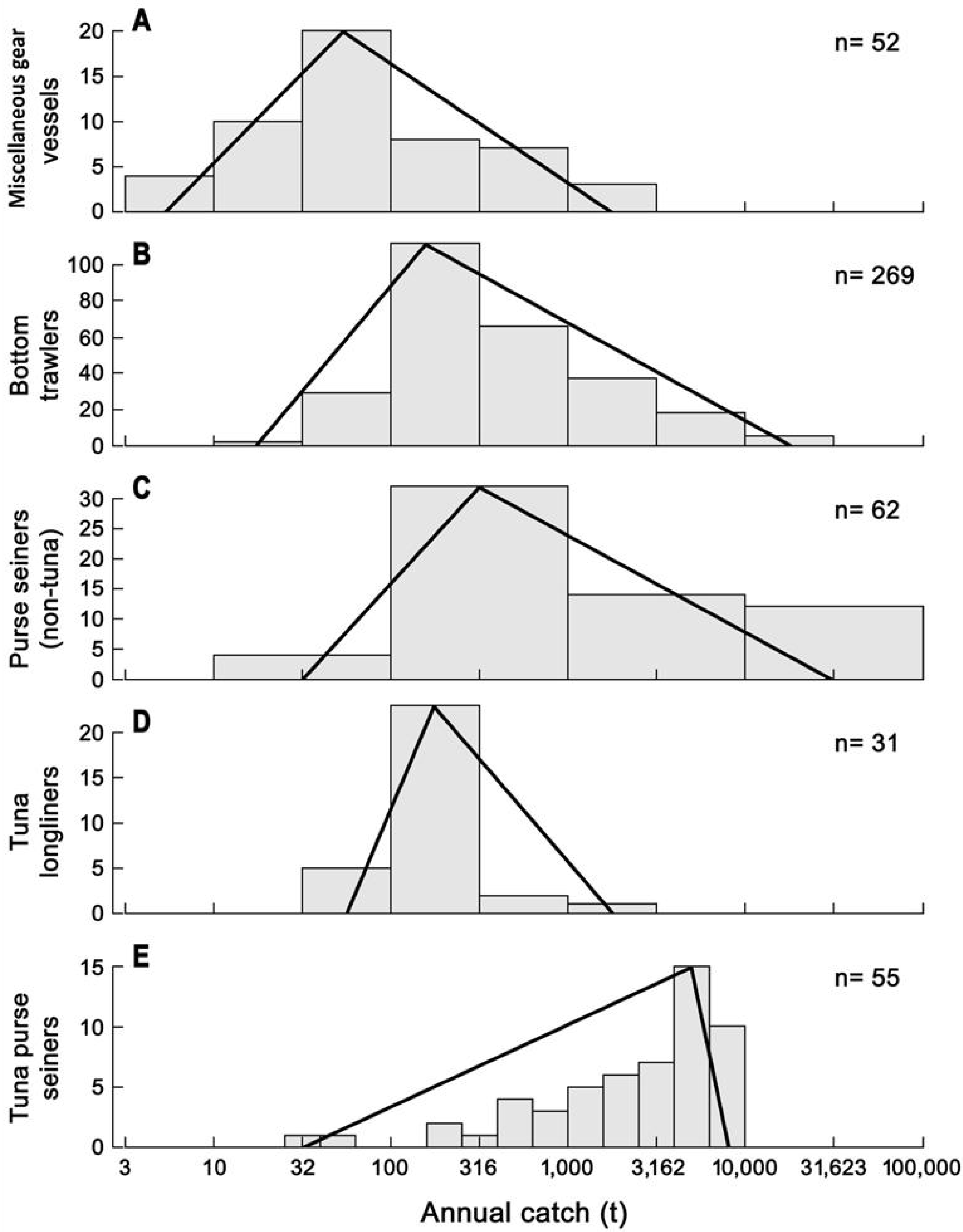
A
n= 52
Miscellaneous gear vessels
0
5
10
15
20
B
n= 269
Bottom trawlers
0
20
40
60
80
100
C
n= 62
Purse seiners (non-tuna)
0
5
10
15
20
25
30
D
n= 31
Tuna longliners
0
5
10
15
20
E
n= 55
Tuna purse seiners
0
5
10
15
3
10
32
100
316
1,000
3,162
10,000
31,623
100,000
Annual catch (t)

Fig 2

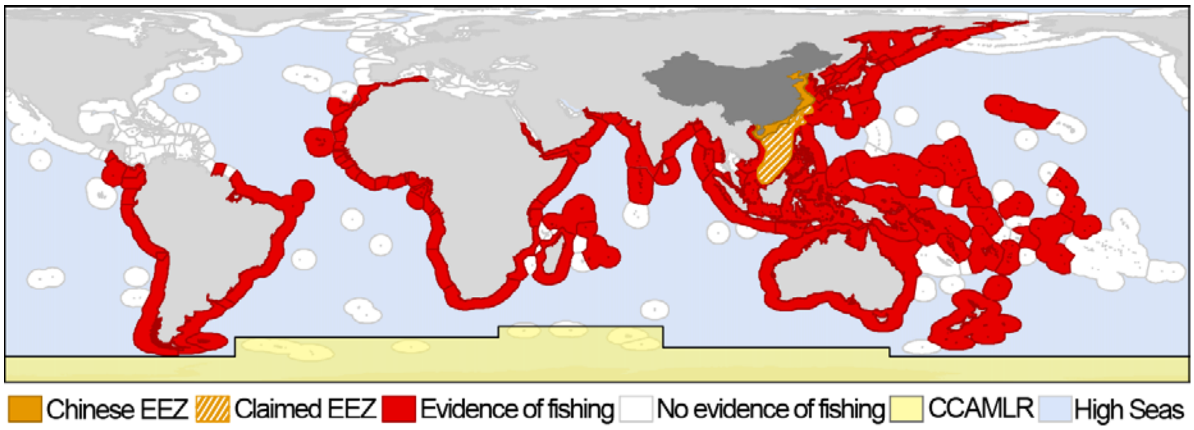
Chinese EEZ
Claimed EEZ
Evidence of fishing
No evidence of fishing
CCAMLR
High Seas

Fig. 3

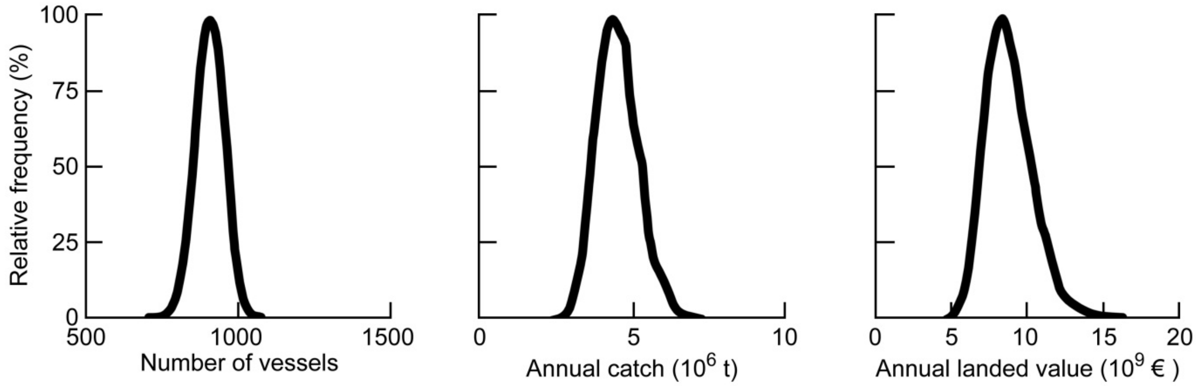
100
75
50
25
0
Relative frequency (%)
500
1000
1500
Number of vessels
0
5
10
Annual catch (10^6 t)
0
5
10
15
20
Annual landed value (10^9 €)

Fig. 4